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Review Article

PISCICIDES IN TROPICAL FRESHWATER AQUACULTURE – AN OVERVIEW

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Application of piscicides of varying nature and compositions are widespread as part of the prestocking management of nursery ponds in tropical carp culture practices. The effectiveness, economic aspect as well as environmental consequences are widely discussed. Chemical piscicides though are very fast effective; there is an inherent risk of residual and colateral impact upon the nutrient dynamics of the pond ecology. Application of dimethyl = 2 : 2 dichlorovenyl phosphate (DDVP) results in N limitation, whereas, application of urea [$CO(NH_2)_2$] in combination with bleaching powder [Ca(OCl)Cl] favours P limitation. Piscicides of plant origin are safe, economical, imparts short term negative impact upon the biogeochemical cycling microbs unlike that of chemical compounds. Herbal piscicides upon decomposition favours N : P ratio to be in the desirable range of 4 : 1- 8 : 1. Understanding on the subject is limited in term of pisicicidal impact upon the microbial as well as planktonic profile of the pond culture system

Key words: Biogeochemical cycling, N: P ratio, Piscicides, Residual impact

Efficient pond fish farming entails small, seasonal ponds preferable as they facilitate effective control of environmental conditions and also because of automatic destruction of predatory and weed fishes by complete dewatering of the pond. In contrast, complete draining of deep perennial water bodies are economically intensive, therefore, some particular steps must be adopted to remove or control predatory and unwanted fishes (Jhingran, 1991) for getting maximum survival rate and production in carp culture. Unwanted or weed fish are smaller varieties of fishes that occur either naturally or accidentally introduced primarily along with the carp spawn into the fish ponds (Rath, 1993). The negative impact of predatory and weed

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fishes in nursery has been discussed much earlier by Alikunhi (1957); Ibrahim (1957) and Choudhuri (1960). They not only compete for food and dissolved oxygen but also compete for space with the cultivable variety of fishes (Chakroff, 1993 and Rath, 1993). Weed fishes have high fecundity and they ripen sexually very fast (Jhingran, 1991). Tripathy and Sharaf (1974) listed *Puntius sophore* followed by *Chela laubuca, Amblypharyngodon mola* and *Rasbora daniconius* as highly destructive and observed that they took a heavier toll of carp spawn within 24 hrs. than the frog lets, tadpoles or the aquatic insects.

Eradication of predatory and pest fishes

In freshwater ponds, removal of predatory fishes has become one of the most important prestocking management practices for scientific management of carp culture (Chatterjee and Ganguli, 1993). In earlier practices, eradication of unwanted fishes was done mainly through hook and line with baits. However, the customary method of removing unwanted fishes from nursery pond is by repeated drag netting (Jhingran, 1991). Moreover, by using screening devices at the inlet, the entry of weed and predatory wild fishes can be reduced to a large extent (Lee, 1973 and Pillay, 1995). Methods like dewatering and desilting of ponds, repeated netting operations, hooks and lines with baits are found to be incomplete and uneconomical (Rath, 1993). Therefore, limited poisoning of the pond with selective toxicants gradually became popular for the purpose.

Piscicide

According to Jhingran (1991), a suitable piscicide is one which (i) effectively kills the target organisms at fairly low doses and is not injurious to the people and cattle who may use the water, (ii) does not render the affected fish unsuitable for human consumption, (iii) gets quickly nullified in water, (iv) leaves no cumulative adverse effect in pond, (v) easily available and at the same time economical. There are several chemicals and herbal poisons which are used extensively as piscicides for eradication of predatory fishes. Piscicides or piscicidess can be grouped as per their source of origin or of their chemical nature. Accordingly, they can be grouped as (i) Plant derivatives and (ii) chemical compounds like (a) organophosphate compounds and (b) chlorinated hydrocarbons (Jhingran, 1991; Rath, 1993 and Mahapatra and Thosar, 1999).

Herbal piscicides

There are quite good number of plant derivatives which could be used for fish poisoning. Generally to avoid the hazardous effects of chemicals some less toxic native plant derivatives are now used in India as fish poisons (Chatterjee and Ganguli, 1993). Plant-derived saponins have been widely used in non-intensive aquaculture operations throughout Asia and Africa and are attractive for the control of aquatic pests because of their low toxicity to mammals (Clearwater *et al.*, 2008). However, the most common herbal poison used in fish pond is rotenone inherent in derris (*Derris elliptica*) root powder. Rotenone is the main piscicide used internationally for eradicating and controlling pest fishes in freshwaters (Willis and Ling, 2000 and Rowe, 2003). Chemical eradication using rotenone has been used for fisheries management in Canada and the USA since the 1930s (Finlayson *et al.*, 2002), and also in Australia for about 45 years (Rayner and Creese, 2006). The use of rotenone has been very limited in New Zealand (Ling, 2003 and Rayner and Creese, 2006). Lake Parkinson was treated to eradicate all fishes, including grass carp (*Ctenopharyngodon idella*) following their introduction to remove nuisance water plants (Ling, 2003). A bait form of rotenone, developed in the USA (Prentox®), was used in Lake Waingata to remove grass carp in 1999 (Rowe, 1999). Other plant derivatives used in fish ponds are tea seed cake, tobacco waste and powdered croton (*Croton tiglium*) seed etc. (Markling, 1992; Chakroff, 1993 and Chiayvareesajja *et al.*, 1997).

The plant derived piscicides are environmentally benign compared to the chemical toxicants because they are biodegradable and act as manures in due course (Mahapatra and Thosar, 1999). They are believed to be less hazardous to farmers and non-target species, do not result in resistance problem, easily bio-degradable than the synthetic ones and also, the environmental side effects are insignificant. However, such popular view is not supported by elaborate research works, primarily because such studies have primarily been concentrated mainly on rotenone. Moreover, the target specificity of majority of the plant derived piscicides are not rigid (Harborne, 1979 and Chandler and Marking, 1982). Even certain plant derived piscicides are far from safe to humans e.g. croton oil is one of the most potent naturally occurring co-carcinogens to human beings. Besides it is the powerful contact poison which causes ulceration of the skin, dermatitis and other potentially serious side effects (Seigler, 1979). Likewise, rotenone derived from derris root powder is proved to be hazardous to workers as inhalation may result in respiratory paralysis (FAO, 1997). Consequently, use of rotenone is strictly controlled by many countries. Therefore, it is evident that the intensity of hazards associated with the plant derived piscicidess is not critically reviewed because of the lack of sufficient literatures. Doses of different piscicides prescribed by different authors showed in Table 1.

Chemical piscicides

The application of commercial pesticide formulations for the control of predatory fish is well documented (Jhingran, 1991) and is widespread throughout the tropics despite their obvious hazards to the user, unpredictable biodegradability in the aquatic medium, persistence, and lack of target specificity. Their extreme potency as fish poisons, easy availability and cost-effectiveness has made them a popular choice (Perschbacher and Sarkar, 1989 and Jhingran,1991). But such pesticides even at very low concentration may exert crucial effects on the endocrine system as well as negative impact on the reproduction and the

Table 1. Doses of different piscicides

Author	Dose	Test organism	Piscicide- Plant origin
Bhatia (1970) Bhatia (1970) Banerjee (1991) Nath (1983) Sarkhel (2002)	60 ppm 200-250 ppm 75 ppm 200 ppm	**All predatory and weed fishes** *Channa punctatus*	 Mahua oil cake
Hall (1949) Das (1969) Shirgur (1972), Banerjee (1991) Jhingran (1991)	0.5 ppm 11-39 ppm 150 ppm 6-10 ppm	*Mugil parsia, Channa punctata* All weed and predatory fishes	Derris root powder
Tang (1967) Banerjee (1991)	12-15 ppm 100-200 ppm	Snails and aquatic organisms	*Nicotiana tabecem*
Pillay(1995) Chiayvareesajja *et al*. (1997)	216 kg/ha tea seed cake + 144 kg quicklime 25 ppm quicklime	*Clarias* sp., *Cyprinus carpio*, *Gambusia* sp., *Oreochromis niloticus, Puntius gonionotus*	Tea seed cake
Banerjee (1991)	100-200 ppm	-	Tea seed powder
Banerjee (1991)	200 ppm	-	*Barringtonia acutangula*
Jena (1979) Banerjee (1991)	250 ppm	-	*Tamarindus indica* (Seed husk)
Banerjee (1991)	250 ppm		*Acacia moniliformes*
Chiayvareesajja *et al*., (1997)	25 ppm	*Clarias* sp., *Cyprinus carpio*, *Gambusia* sp., *Oreochromis niloticus, Puntius gonionotus.*	*Maesa ramentacea*
Hashimoto *et al*., 1991	100 ppm	*Oryzias latipes*	*Edgeworthia chrysantha*

development of aquatic organisms (Froese, 1997). In broad classification such chemical pesticides belong to two distinct categories as per their chemical nature like organophosphates and chlorinated hydrocarbons.

Organophosphates

In India, three organophosphate compounds like thiometon, DDVP and phosphamidon (Srivastava and Konar, 1965 and Konar, 1969) have been found successful for killing fish on experimental basis. Though, Shrestha *et al*. (1987) used malathion for preparing nursery pond but the most effective and commonly used organophosphates are DDVP, thiometon and phosphamidon (Rath, 1993). Organophosphate compounds have more detrimental effect than other piscicides (Thosar and Das, 1984) because of their extremely high application rates often employed (e.g. > 200 mg/L) but they are comparatively less toxic than chlorinated hydrocarbons to fish (Mahapatra and Thosar, 1999).

DDVP (0:0) dimethyl= 2:2-dichlorovenyl phosphate is commercially available in India as a spray formulation (Jhingran, 1991). Mortality of snails (*Pila* sp.) of zoonotic importance was established under laboratory conditions by using organophosphate piscicides (Panigrahi, 1998). Acute toxicity of DDVP on fish was studied by Pal (1983) and Perschbacher and Sarkar (1989). It has been observed that DDVP with a mixture of non-ionic detergent is more effective than individual toxicant (Hossain *et al*., 1987).

Organochlorins

Chlorinated hydrocarbons like aldrin ($C_{12}H_8Cl_6$), dieldrin ($C_{12}H_8Cl_6O$), endrin ($C_{12}H_8Cl_6O$) and taffdrin- 20 etc. had been in use for the eradication of predatory and weed fishes both in India as well as in the tropics (Jhingran, 1991 and Rath, 1993). Organochlors could be used economically in cleaning ponds of miscellaneous fishes and other unwanted organisms. Chlorinated hydrocarbons are very toxic to fishes in extremely low doses and persist in the medium as stable compounds; also they might be biomagnified and bioaccumulated in the food chain (Mahapatra and Thosar, 1999). Chakroff (1993) suggested not to use chemicals like endrin, dieldrin, DDT etc. in ponds as they can persist in the sediment for years and therefore, fish kill may occur afterwards. Organochlorin compounds have also been suggested as contributing to the epizootics of ulcerative fish diseases in South- East Asia (Perschbacher and Sarkar, 1989). Therefore, the use of organochlorine compounds has recently been prohibited in India. Doses of different piscicides (organochlorine and organophosphate groups) prescribed by different authors showed in Table 2.

Table. 2. Doses of different piscicides (organochlorine and organophosphate groups)

Author	Dose	Test organism	Picicide
			Organophosphates
Jhingran (1991)	3-30 ppm	Most unwanted fish	DDVP
Rath (1993)			
Konar (1964)	0.5 ppm	Phytoplankton	
Rath(1993)	0.003-0.5 ppm	Aquatic insects	
			Chlorinated hydrocarbons
Jhingran (1991)	0.2 ppm	All predatory and weed fishes	Aldrin
Chaudhuri (1960)	0.001 ppm	All weed fish	Eldrin
Chaudhuri(1960)	0.01 ppm	All weed fish	Dieldrin
Jhingran (1991), Rath (1993)	0.05 ppm	Blue gill , Bass	Taxophene
Chaudhuri (1960)	0.15 ppm	Blue gill, Bass	DDT
Chaudhuri (1960)	0.2 ppm	Blue gill, Bass	Methoxychlor
Chaudhuri (1960)	0.2 ppm	Blue gill, Bass	Chlordane
Chaudhuri (1960)	0.1 ppm	Blue gill, Bass	B S C
			Other synthetic agents
Mohanty *et al*. (1993)	3 ppm + 5 ppm	All weed fish	Urea + Bleach
R Ram *et al*. (1988)	5 ppm Cl + 5 ppm NH_3	*Channa punctata* (fry)	
Ramaprabhu *et al*. (1990)	5 ppm	All weed fishes	Un-ionised NH_3
Tripathy *et al*. (1980)	50 ppm	Unwanted fish, crab,	Bleaching powder
Perschbacher & Sarkar (1989)	-	-	Aluminium phosphide

Other type of synthetic piscicides

There are several other type of synthetic compounds which are very often used for eradication of unwanted or weed fishes. Inorganic compounds like cyanides, potassium permanganate and quick lime are used in different countries, but preferences vary from region to region. Endosulfan is a registered piscicides used extensively to control undesirable organisms (Paul and Rauth, 1987). Antimycin is also very toxic to carp and selectively kills some undesirable species but is ineffetive at high pH (Markling, 1992). Antimycin is a cellular respiration inhibitor and is used in cellular physiology studies for its specific action as an electron transport inhibitor, specifically for mitochondrial complex III (Eighmy *et al*., 1991 and Doeller *et al*., 1999). Antimycin is particularly toxic to scaled fishes, is less toxic to channel catfish (*Ictalurus punctatus*), and has low toxicity to other aquatic organisms (Finlayson *et al*., 2002). Juvenile life stages are more susceptible than adult fishes to antimycin (Finlayson *et al*., 2002).

Ammonia is successfully employed for eradication of unwanted fishes and also it acts as a fertilizer afterwards (Rath, 1993). The combination of commercial grade bleaching powder and urea having equal proportion of 5 ppm each of chlorine and ammonia has been found to be effective, economical and is also considered advantageous (Ram *et al*., 1988). Though, singly anhydrous ammonia (Ramachandran, 1960 and Ramaprabhu *et al*., 1985, 1990) and commercial bleaching powder (Tripathy *et al.,* 1980) have been used for eradicating unwanted and predatory fish, combination of urea (as source of ammonia) and bleaching powder proved to be better. Urea, besides acting as a piscicide in such combination also helps in the growth of natural fish food organisms, such as algae, diatoms and rotifers and can be considered beneficial in fish culture system (Mohanty *et al*., 1993). Application of urea (200 kg/ha) is an established fertilization measure in composite fish culture operations in India (Anon, 1981). When it is used as a piscicide the ammonia liberated would act both as piscicide and weedicide. Again ammonia treatment with superphosphate resulted in significantly higher growth of carp seed (Tripathy *et al*., 1991). The growth and survival of carp fry in pond treated with bleaching powder was comparable with those in oilcake treated ponds. Therefore, bleaching powder can effectively based as piscicide without adversely affecting the growth and production of carp seed (Ram *et al*., 1988).

Fish killing mechanisms of the piscicides

Different piscicides act differently at the physiological and biochemical level which ultimately results in fish kill. Also, the duration of toxicity in an aqueous medium varies. Saponin derived from mahua oil cake (4-6%) and tea seed cake is the active ingredient that kill the fishes (Perschbacher and Sarkar, 1989). Saponin act as haemolytic agent, dissociate the bonding pattern of haemoglobin molecules and also responsible for breakdown of the bio-membrane of red blood corpuscles (Jhingran, 1991 and Chatterjee and Ganguli, 1993). Such toxicity following mahua oil cake application lasts only for 2 days after which fish may be killed due to oxygen deficiency or due to CO_2 liberated in large quantities as a consequence of decomposition of mahua oil cake (Nath, 1983). Fishes on being affected by saponin are reported to appear in a distress condition at first after which they become inactive and loss their balance. Then they sink to the bottom and lie on as if in a state of coma and finally die (Bhatia, 1970). Other saponin containing plant derivatives like tamarind seed (*Tamrindus indica*) husk (Jena, 1979) and sugarcane jaggery (Jhingran, 1991) also act as haemotoxic to fish. Likewise, derris root powder which contains 5% rotenone ($C_{23}H_{22}O_6$) as active ingredient damages the respiratory system of fishes (Jhingran, 1991) and depending upon the dosage used, the toxic effect of derris powder may last upto 12 days (Jhingran and Pulin, 1985). Exposure of air-breathing catfish, *Heteropneustes fossilis* to various concentrations of ethyl alcohol extract of a piscicidal plant, *Zanthoxylum armatum* revealed significant reversible inhibition of enzyme activity in liver, brain and muscle tissues (Ramanujam and Ratha, 2008). Hashimoto *et al*. (1991) observed that presence of two steryl glycosides (sitosterol glucopyranoside acylated with linoleic or linolenic acid) in a plant (*Edgeworthia chrysantha*) which have piscicidal activities.

Organophosphate compounds act in general as neurotoxins, irreversibly inhibits the enzymatic pathway particularly the activity of cholinesterases resulting in accumulation of acetylcholine which is a neurotransmitter substance at parasympathetic neuroeffector junction, autonomic ganglia, somatic myoneural junction and probably certain central nervous systems regions (Ghatak and Konar, 1993). However, such compounds having P (O) group are severely toxic and strong inhibitors of acetylcholinesterase compared to the others having P(S) group (Dash, 2001). Similar to organophosphate compounds, chlorinated hydrocarbons also act as neurotoxins to fish but it is highly toxic and adversely affect the other aquatic biota (Mahapatra and Thosar, 1999). In shallow ponds, it acts quicker during sunny days but may have hardly any action in deeper water exceeding the depth of about 20 ft. It's action takes about 2-3 hrs to affect Indian major carps and 4 to 8 hrs to hardy fishes like *Tilapia* and bottom dwelling fishes like *Materopneustes tossihis, Clarias batrachus* etc. (Rath, 1993).

Other than these piscicides, mixture of urea [CO $(NH_2)_2$] and bleaching powder [Ca (OCl) Cl] is also applied frequently as a piscicides (Tripathy *et al.,* 1980). Urea, after application into the pond is hydrolysed to ammonia (NH_3) which is liberated within 24-48 hrs. at a temperature ranging from $23^0 - 30^0$C, while hypochlorous acid (HOCl) is produced instantaneously from the chlorinated compound, bleaching powder under the prevailing environmental conditions. This hypochlorous acid, being a strong oxidizing agent is readily produced in the presence of reducing substances namely, NH_3, Mn^{+2}, Fe^{+2} etc. of the environment resulting in 'chlorine demand' of water. In the pond ecosystem, chloramines usually termed "Combined Residual Chlorine" (CRC) are formed with the operation of oxidative-reduction process in the presence of both NH_3 and hypochlorous acid (Mohanty *et al.*, 1993). The rate of chloramines formation largely depends upon ambient pH of the system (Mattice *et al.*, 1981).

On the other hand, un-ionized ammonia (NH_3) and Free residual chlorine (FRC) [HOCl + OCl] are primarily responsible for fish kill when ammonia and chlorine compounds are employed separately in fish ponds. However, such effects are somewhat pH and temperature mediated. But when combinations of ammonia and chlorine are used, resultant Total residual chlorine (TRC) (NH_2Cl + $NHCl_2$ + NCl_3) becomes the toxic component in which both Free residual chlorine (FRC) and Combined Residual Chlorine (CRC) are represented. However, the formation of FRC and CRC depends mainly on the molar ratio of both ammonia and chlorine present in the system. The break point of ammonia in the presence of chlorine occurs within a molar ratio of 1 to 2 with complete disappearance of all ammonia and chlorine from water (Fair and Geyer, 1954).

In aquaculture ponds, 3–5 mg total N/L must be achieved through application of urea 24–48 hrs before application of bleaching powder to attain 5 mg chlorine/L for 100% fish kill within 1 hr of application (Ram *et al.*, 1988 and Mohanty *et al.*, 1993). Crustacean and molluscan death also occurred within 1–24 hrs (Ram *et al.*, 1988 and Mohanty *et al.*, 1993). In a field trial, minnows and weed fishes were the most sensitive, and carps and predators the least sensitive (Ram *et al.*, 1988). The piscicidal effect at higher level of chlorine as suggested by Tripathy *et al.* (1980) is due to the toxicity of free residual chlorine but according to Mohanty *et al.* (1993) the combined residual chlorine is mainly responsible for fish kill. Individually free chlorine, even at low concentration in natural waters has been reported to be toxic to fish by causing osmotic imbalance (White, 1955 and Tomkins and Tsai, 1976). Similarly, increased ammonia concentration adversely affects enzyme-catalysed reactions, membrane stability and gill function resulting in fish mortality particularly under high pH and temperature (Colt and Armstrong, 1979). The total ammonia concentration in a water body required for 100% eradication of pest fishes, using lime to increase the pH to 10, could be as low as 25 mg NH_4–N/L (Clearwater *et al.*, 2008). Ammonium sulphate is most effectively used in conjunction with a lime treatment, to first increase the pH with lime, thereby increasing the toxicity of the ammonia (Kungvankij *et al.*, 1986).

Effects on water quality parameters

The effect of piscicides on water quality parameters is dependent upon the nature of the compounds used for the purpose. When mahua oil cake was applied in ponds, the dissolved oxygen content of the pond decreased upto trace within 24 hrs followed by a slowly increasing trend after 8-11 days. The BOD of pond water was high (40-44 ppm) which persist upto 5 days (Nath, 1983). In contrast, free CO_2 content showed increasing trend with insignificant change in total alkalinity (Nath, 1983). However, Jana *et al.* (1987) observed that bicarbonate alkalinity, total hardness, chloride concentration were greatly increased in mahua oil cake treated water. On the other hand, DDVP as a piscicide resulted in insignificant fluctuations of water pH, temperature and DO but the colour and odour of water changed significantly. The combined application of bleaching powder and urea did not result in any noticeable change in water quality parameters, excepting an increase in the chlorine content (Ghatak and Konar, 1992).

Effects on nutrient status

Chemical pesticides as piscicides are though very effective in killing the target as well as non target fishes, they are liable for exerting negative effects on the biology of the fish pond as a whole. Because toxic chemicals impaired the normally high self purification capacity of running waters when they kill or harm the bacteria responsible for self purification process (WBGU, 1999). Negative impacts of a wide range of chemical piscicides on biogeochemical cycling bacteria like cellulose decomposing bacteria, ammonifying bacteria, nitrogen fixing bacteria, denitrifying bacteria, ammonia oxidising bacteria and phosphate solubilizing bacteria of both soil and water was well documented (Sarkhel, 2002 and Sarkhel and Das, 2005).

When mahua oil cake was applied in ponds, the values of phosphate and different forms of nitrogen of water were greatly increased (Nath, 1983 and Jana *et al.*, 1987). Significant increase in phosphate concentration, after mahua oil cake application is due to its biodegradation (Ghatak and Konar, 1993) and the released nutrients help in increasing the productivity afterwards (Nath, 1983). The phosphate and total nitrogen content were found to be high after mahua oil cake treatment upto 13th day until the nutrients were taken up by phytoplankton and algae (Nath, 1983). The maximum toxicity develops during the period of 3-7days of cake application and was evident from the sharp rise in the concentration of NH_3 and CO_2 of water during this period (Jana *et al.*, 1987). This is because, a high rate of oxidation was observed in the water bodies with high DO levels, while the process of denitrification proceeds more rapidly in water which lacked sufficient DO (Sugiyama and Kawai, 1978). Application of DDVP as piscicides in pond resulted in the release of large amount of phosphate in pond water (Sarkhel, 2002) but no significant fluctuation in the level of nitrite and nitrate (Ghatak and Konar, 1992). On the other hand, when urea and bleaching powder was applied it increased the level of free chlorine and larger amount of ammonia with subsequent rise in nitrate and nitrite (Ram *et al.*, 1988 and Mohanty *et al.*, 1993). In case of urea and mahua oil cake application, increase in the organic carbon level of soil as well as water was noticed (Ram *et al.*, 1988). This is because mahua oil cake instantly enriches the organic carbon pool upon decomposition whereas; urea application enhances primary production by supplying inorganic nitrogen to the growing phytoplankton population. As a result, application of bleaching and urea mixture as piscicides results in a P limited condition with high N : P ratio, whereas, DDVP application results in N limited environment in the aquatic phase. However, application of mahua oil cake favoured the environment with a congenial N : P ratio of 4.5-5.5 (Sarkhel, 2002).

Effects on pond productivity

A reduction in gross as well as net primary productivity immediately after application of mahua oil cake was observed and the rate of such reduction was directly dose dependent (Paul and Zohra, 2000). Toxicity of mahua oil cake was found to be responsible for the sharp decline of phyto and zoo-planktons within 3-5 days of treatment (Jana *et al.*, 1987). As mahua oil cake subsequently acts as a manure in pond following its decomposition (Banerjee *et al.*, 1987), it has got the utility in adding fertility to the water for the growth of plankton besides controlling weed fishes (Acharjee and Biswas, 1995). Highly significant increase in primary productivity and growth of fish at 3200 kg/ha of mahua oil cake application in combination with 1125 kg/ha of lime was observed. However, a period of 30-45 days should be allowed after application of mahua oil cake before stocking, for maximum benefits from the cake (Lakshman, 1983).

DDVP also significantly reduced both phytoplankton and zooplankton population at sublethal concentration and subsequently it resulted in reduction of GPP and NPP (Pal and Konar, 1985). However, combination of urea and bleaching powder did not cause any adverse effect on productivity. Though initial reduction in planktons was noticed, a subsequent increase in plankton population as well as productivity was observed (Shyam *et al.*, 1993).

Comparative persistence of piscicide

In general, the plant derivatives are bio-degradable in water because they undergo decomposition and converted to manure once their toxic action is nullified (Mahapatra and Thosar, 1999). The effectiveness of saponin persists for about 2 days in water after application of mahua oil cake (Nath, 1983). The toxicity persistence of tea seed cake and *Maesa ramentacea* was not significantly different and fish can be released four days after applying either piscicides (Chiayvareesajja *et al.*, 1997). Organophosphate piscicide shows the abnormal behaviour of fish within first 6 hrs of exposure while abnormal activities increased after 6-8 hrs of exposure with organochlorine piscicides (Panwar *et al.*, 1976). Chlorinated hydrocarbons are more toxic to fishes and persist in the medium as stable compound, also these chlorinated hydrocarbons get deposited into the sediment (WBGU, 1999 and Roychaudhuri, 2002) (Table 3),

Table 3. General persistence of chlorinated hydrocarbons in soils

95% disappearance years	Pesticide
1-6	Aldrin
3-5	Chloradane
4-30	DDT
5-25	Dieldrin
3-5	Heptachlor
3-10	Lindane

Table 4. General persistence of organo-phosphorus pesticides

75-100% disappearance	Pesticide
12 week	Diazinon
1 week	Malathion
1 week	Parathion

therefore rendering its poisonous effect for long (Chakroff, 1993). They may be biomagnified and bio accumulated in the food chain (Mahapatra and Thosar, 1999). Therefore, in recent years organophosphate are preferred over organochlorines due to its less persistence (Table 4) as well as residual effect (Mahapatra and Noble, 1993). On the other hand, the combination of urea and bleaching powder has a short residual toxicity in fish culture ponds (Janakiram *et al.*, 1988). But as the residual chlorine might be very toxic to aquatic life; dechlorination is often required prior to the discharge of treated water to receiving waters (USEPA, 1999a). In addition, chlorine compounds can react with organic compounds in natural waters to form persistent chlorinated organic byproducts (e.g. trihalomethanes, haloacetic acids and chlorite) in low concentrations (USEPA, 1999b). However, the one-off use of chlorine as a piscicide would be unlikely to produce significant long-term environmental effects.

Comparative cost effectiveness

Cost of piscicide like any other inputs is a major consideration for choosing the right piscicide by the fish culturist. Of all the piscicides, plant derivatives are comparatively cost effective. Among others, extracted rotenone from plant derivatives is a registered toxicant but it is thought to be expensive by some fish managers (Markling, 1992). However, it is of moderate cost compared to organophosphate compounds which is too costly to be attractive to the fish culturists (Perschbacher and Sarkar, 1989). The combination of commercial grade bleaching powder and urea has been found to be most economical and advantageous among the inorganic piscicides (Ram *et al.*, 1988). Because, dual advantage of piscicidal action and fertilization value is attainable from this combination with benefits of cost effectiveness (Janakiram *et al.*, 1988 and Mohanty *et al.*, 1993). Over-application of piscicides can be costly and result in high mortality of aquatic invertebrates. Similarly, specific recommendations for applications seldom exist where sunlight and organic matter could significantly alter the toxicity of piscicides (Rupp, 2008).

Detoxication of ponds treated with piscicides

Detoxification of piscicide treated pond is an important step before subsequent stocking of fish seed into the pond water. Most of the plant originated poisons degrade and disappears from the water within 7-12 days (Chakroff, 1993), whereas, the chemical poisons needed more time to be detoxified. The use of detoxifying materials like charcoal powder, sulphuric acid, potassium permanganate etc. has been recommended in the chemically treated ponds to remove the toxicity within a short period. These detoxifying materials can be used as charcoal powder @ 20-25 ppm, H_2SO_4 @ 100 ppm, $KMnO_4$ @ 5 ppm which can detoxify the pond within 4-5 days. Raw cowdung @ 18,000 kg/ha is also found effective in detoxification of treated water (Rath, 1993). The detoxification period of bleaching powder was lengthy (Perschbacher and Sarkar, 1989). But application of urea (200 kg/ha) is an established fertilization measure in composite fish culture operations in India (Anon, 1981), so when urea is used as a component of treatment along with bleaching powder it shorten the detoxification period of the pond and act as a fertilizer afterwards (Mohanty *et al.*, 1993). Antimycin can be removed from water by using activated carbon in a water treatment system (Dawson *et al.*, 1976).

The toxic period of mahua oil cake can be reduced from 20-25 days to 7-10 days or even less by aerating the water mechanically or by suitable doses of oxidising chemicals (Jhingran, 1991). It was observed that $KMnO_4$ solution @ 2.4 ppm indicate no detoxification of saponin, although $KMnO_4$ solution effectively detoxify rotenone from derris root powder. Similarly, treatment of mahua oil cake applied pond water with lime @ 200 ppm indicate no detoxification of the saponin, but it was only possible to reduce the toxic period of saponin by aerating the pond water with suitable aeration device (Nath, 1983). If single superphosphate is used along with mahua oil cake, it compensates the deleterious effect of the cake. Therefore, use of mahua oil cake at high amount or it's frequent addition should be avoided (Sarkar, 1988).

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